U. S. NAVAL AIR DEVELOPMENT CENTER

JOHNSVILLE, PENNSYLVANIA

Aviation Medical Acceleration Laboratory

NADC-MA-6307 24 July 1963

The Successive Differentiation of a
Lever Displacement Response

Bureau of Medicine and Surgery
SubTask MR005.13-0002.16 Report No. 11

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SUMMARY

Maximum displacements of lever presses by rats were recorded under 8 successively-smaller "reinforcement zones" (RZ). The largest RZ included displacements from 3.29° to 44.01°; the smallest, from 23.65° to 28.74°. Work expended was linearly proportional to displacement. As the RZ decreased, displacement distributions reflected a "least effort" tendency: distributions peaked at the lower limit of RZ and most non-reinforced presses fell just below the lower limit. Successive distributions (a) differed significantly, (b) showed reduced variability, and (c) indicated more presses, more reinforcements, and more presses per reinforcement. The effect on a given response class was less, relatively, when that class was eliminated from the RZ than it was when a higher response class was eliminated. A modified differentiation procedure was recommended.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES

LIST OF TABLES

The successive differentiation of a response is a procedure by which some particular form or property of a response is approached gradually by means of selective reinforcement and extinction. Although the concept of successive differentiation is widely accepted and used, there are, in fact, relatively little experimental data on differentiations. The purpose of this report is to help fill the need for this type of data, with particular reference to the development of a differentiation. A quantitative account is given of the development of a differentiation in which (a) the response classes fall on a continuum and (b) the reinforced response class is defined by both upper and lower limits. The response property measured is lever displacement. Because of the characteristics of the special response lever used, the work expended by a subject in pressing the lever arm is linearly proportional to the displacement of the lever arm.

METHOD

Subjects

Five male albino rats of Sprague-Dawley strain served as Ss. They were about 146 days old on the first test day.

Apparatus

Test Box. The test box was 8 in. wide, 9 1/8 in. long and 7 5/8 in. high. To eliminate cues and distractions, the test box was enclosed in a picnic ice box, and all programing and recording equipment were located

in another room. A blower attached to the ice box provided air circulation between room air and test box air, and thermostatically-controlled air coolers and heaters supplemented the central heating system to maintain temperature within about 1° of 22.5° C. A constant low level of illumination was provided in the test box by two small lamps mounted on the wall above the lever. Water reinforcements were delivered by a 0.014 cc cup which projected 1/4 in. above the floor at a point 2 in. to the side of the lever arm. A food container was mounted on one wall; the response lever was mounted on the opposite wall. In its resting position the arm of the response lever was at an angle of 23° above the horizontal and extended about 3/4 in. into the compartment. In this position, the T-bar handle was 2-7/16 in. above the grid floor.

Response Lever. The response lever and associated calibration procedures are described in detail elsewhere (Herrick & Karnow, 1962). In short, one end of the lever arm terminated in the form of a horizontal rod (T-bar). The displacement of the T-bar was classified into intervals of arc or "lever positions". The interval between the resting place of the T-bar and 3.29° of arc was called the Home Position. Each of the remaining eight Lever Positions, successively numbered 1 through 8, spanned approximately 5.09° (or 4.51 mm) of arc. The exact arcs represented by Positions 1 through 8 were 5.05°, 5.05°, 5.10°, 5.15°, 5.15°, 4.86°, 5.15°, and 5.19°, respectively. A minimum force of 26,500 dynes (27 g) was required to depress the T-bar, and this minimum

force requirement remained constant, within about 2%, throughout the total excursion of the T-bar. Because of this force constancy, no information on the displacement of the T-bar was available to the rat from force cues.

With the lever mechanism, the work expended in depressing the T-bar is linearly proportional to its displacement: Work = 134, 620 θ, with work in dyne-cm and θ in radians. Conversion factors relating various units are as follows: 1° of arc of the T-bar is equivalent to 0.8863 mm of arc or 2,349 dyne-cm of work or 2.397 g-cm of work. Thus, taking each of the numbered positions as 5.09°, a press to Position 5 means that the press was between 23.65° [i.e., $3.29^{\circ}+4(5.09^{\circ})$] and 28.74° [3.29° + $5(5.09^{\circ})$] or 20.96 to 25.47 mm of arc and represented between 55,554 and 67,510 dyne-cm or 56.69 and 68.89 g-cm of work. The midpoints of these intervals may be taken as representative of any Position 5 press.

For a description of the relationships between the rat's lever pressing and the physics of the lever mechanism see the apparatus section of an earlier report (Herrick, 1963a).

For each press, the maximum displacement of the T-bar was measured in lever position units. For example, if the T-bar was moved off the Home Position, through Positions 1, 2, 3, 4, stopped somewhere in the interval called Position 5, and then returned to the Home Position, a count was recorded for a press to Position 5. Eight counters recorded this type of information for Positions 1 to 8.

Calibrations. The arc covered by each Lever Position was measured by a dividing head, a milling machine accessory. This device yielded

measurements accurate to .0476° of arc. The minimum force requirement was measured by a specially constructed device that recorded the force applied perpendicularly to the T-bar as a function of T-bar displacement. The mean size of the drop of water used as reinforcement, viz., .014 cc, was determined by measurement of individual drops by a standard gravimetric method, with precautions that precluded loss by evaporation.

Procedure

On the 25 days preceding the conditioning period and on most of the days during the conditioning period (see below), each rat was given access to water automatically in its living cage for 15 min at the same time daily. During the conditioning period each rat was tested for 1 hr daily on weekdays. The termination of the 1-hr test period preceded the beginning of the free watering period by 15 min. Because of an equipment malfunction the 15-min watering period on the weekdays was eliminated on Test Day 22 (see Results) and thereafter. Purina Lab Chow was available in the living cage and the test box.

On the first two test days the rats were reinforced for all presses to Positions 1 through 8. On the next two test days only presses to Positions 2 through 8 were reinforced; on the next two test days, only presses to Positions 2 - 7. This method of systematically decreasing the "reinforcement zone" (RZ) every two test days was continued until only presses to Position 5 were being reinforced. Then, twenty additional days of training were given on this last condition. Reinforcement for a

press within the RZ was delivered at the completion of a press, i.e., immediately after the T-bar returned to the Home Position.

RESULTS

In the following presentation the data are described in lever position units. Information in the method section allows the reader to convert these position units to degrees or mm of arc, or to dyne-cm or g-cm of work. To conserve space, many of the figures and tables presented below do not include the data of all five rats. Usually the data omitted from a given figure may be derived easily from other figures. The Fig. 2 data, for example, may be used to construct the histograms of the two rats omitted from Fig. 1 or to compile tables similar to Table 1.

The phase in which the reinforcement zone (RZ) was decreased systematically will be treated separately. Then, data of the 20 additional days, when only presses to Position 5 were reinforced, will be considered.

Figure 1 provides conventional plots of distributions for 3 of the 5 rats. For the two rats not included in Fig. 1, comparisons of pairs of distributions by the method described in the Fig. 1 caption indicated that every comparison of Rat #30 showed a significant difference, and 9 of the 15 comparisons of Rat #25 showed a significant difference. Combining this information with that of Fig. 1 indicated that, of the 75 comparisons of the distributions, 61 showed a significant difference. The non-significant comparisons more often represented comparisons based on

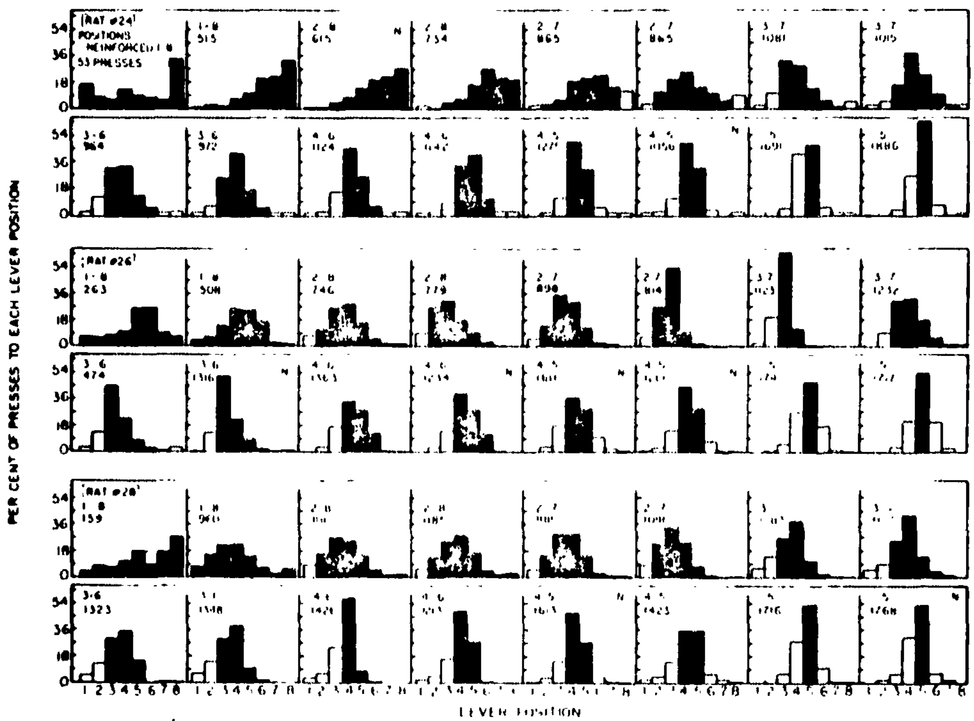

Figure 1. Lever displacement distributions as a function of the size of the "reinforcement zone". Shaded sections of the histograms indicate the lever positions within the "reinforcement zone" The symbol N indicates a distribution that did not differ significantly (.05 level, Kolmogorov-Smirnov two-sample, two-tail test) from the preceding distribution shown for the same rat.

distributions under the same RZ rather than comparisons based on distributions under different RZ; 9 of the 14 non significant comparisons fell in the former category. Also, the non-significant comparisons tended to occur in the later stages of the successive differentiation; 10 of the 14 occurred in the latter half of the successive differentiati on.

In Fig. 1, one should note the differences in the shapes of the distributions initially. Since all presses were reinforced during the first two days, each rat developed some characteristic lever-pressing behavior that differed from that of the other rats. When the data of all five rats were combined, some of these initial differences were obscured.

Another point to be noted in Fig. 1 is the tendency for the distributions to peak at the lower positions within the RZ For example, with RZ of 3 - 7 and 3 - 6, twenty daily distributions were recorded for the five rats. For ten of these distributions the mode was Position 3, and for the other ten the mode was Position 4. For RZ 4 - 6 and 4 - 5, eighteen of the twenty daily distributions peaked at Position 4, and the other two peaked at Position 5.

There was also a strong tendency for the highest number of non-reinforced presses to occur at the position adjacent to the lowest reinforced position. Thus, for the twenty distributions obtained with RZ of 3 - 7 and 3 - 6, of the non-reinforced positions Position 2 always ranked highest. For the twenty distributions obtained with RZ of the 4 - 6 and 4 - 5, of the non-reinforced positions Position 3 always ranked highest

Table 1

Increases (+) and Decreases (-) in the Percentage of Presses to Each Lever Position as the Size of the Reinforcement Zone Decreases. Rat #26.

Reinforcement Zones Compared	Lever Position 1	2	3	4	5	6	7	8	Direction of Median
1-8 and 1-8	-	+	+*	+*	-	-*	-*	-*	.
1-8 and 2-8	+	+*	+*	+	-*	-*	-	-	-
2-8 and 2-8	+	+*	+	-*	-*	-	-	-	-
2-8 and 2-7	-*	-*	+	+*	+	-	-	+	+
2-7 and 2-7	+	+*	+*	-*	-*	-*	-	-	-
2-7 and 3-7	-*	-*	+*	+	-	+	-	-	+
3-7 and 3-7	-	-*	-*	+*	+*	+*	+*	+*	+
3-7 and 3-6	+*	+*	+*	-*	-*	-*	+	+*	-
3-6 and 3-6	-*	+	+*	-	+	-*	-	-	-
3-6 and 4-6	-	-*	-*	+*	+*	+*	+	-	+
4-6 and 4-6	-	-	-*	+*	+	-	+	-	+
4-6 and 4-5	+	+	+*	-	+	-	+	+	-
4-5 and 4-5	+	-	-*	+*	-	-*	-	+	-
4-5 and 5	-	-*	-*	-*	+*	+*	+	-	+
5 and 5	-	-	-*	-*	+*	+	+	-	+

Note. - An asterisk means that the percentage of presses to a given lever position on one day was significantly (.05 level, two-tail test) higher (+) or lower (-) than the percentage on the preceding day. In most comparisons the normal-curve approximation test comparing two percentages (Wallis & Roberts, 1956, p. 429) was used. However, when the percentage values were less than 3% and the number of presses in each distribution was greater than 500, the comparison was based on tables derived from a table (Pearson & Hartley, 1956, p. 185) that evaluates the difference between two Poisson variables.

Table 1 indicates, for one rat, the direction of the change in the daily percentage of presses to each lever position. First, the percentage of presses to the higher positions decreased, and the percentage of presses to the lower positions increased, i.e., the distribution shifted downward toward the lower-numbered positions. This trend was strong enough to result in increases in the percentage of presses to Position 1 even though Position 1 was outside the RZ. After two days of increases in the percentage of presses to the non-reinforced Position 1, there were decreases on Positions 1 and 2 and increases on Positions 3, 4, 5. The next day, when Position 8 was eliminated from the RZ, the distribution again showed a downward shift. On the next two days, when Position 2 was no longer within the RZ, the distribution shifted upward. As Table 1 shows, this oscillation in the direction of the distribution continued as the RZ diminished in size. The last column of Table 1, which shows the change in the direction of the median lever displacement, epitomizes this oscillation.

For all rats, tables similar to Table 1 were compiled. From them, Table 2 was constructed. Since, on the basis of the null hypothesis, the probability that all five rats would show a percentage change in the same direction is $(1/2)^5$ or .031, each entry in Table 2 indicates statistical significance at the .031 level. The table shows that the elimination of the lower positions from the RZ had a more pronounced effect than the elimination of the higher positions.

Figure 2 allows the reader to follow the daily percentage of presses

Table 2

Comparisons in Which All Five Rats Showed an Increase (+) or a Decrease (-) in the Percentage of Presses to a Given Lever Position

Reinforcement Zones Compared	Lever Position 1	2	3	4	5	6	7	8
1-8 and 1-8								-
1-8 and 2-8			+	+			-	-
2-8 and 2-8								
2-8 and 2-7			+	+				
2-7 and 2-7	+	+	+		-	-	-	-
2-7 and 3-7	-	-		+			-	
3-7 and 3-7		-						
3-7 and 3-6		+						
3-6 and 3-6							-	-
3-6 and 4-6	-	-	-	+				
4-6 and 4-6								-
4-6 and 4-5								
4-5 and 4-5								+
4-5 and 5		-	-	-	+			
5 and 5		-						

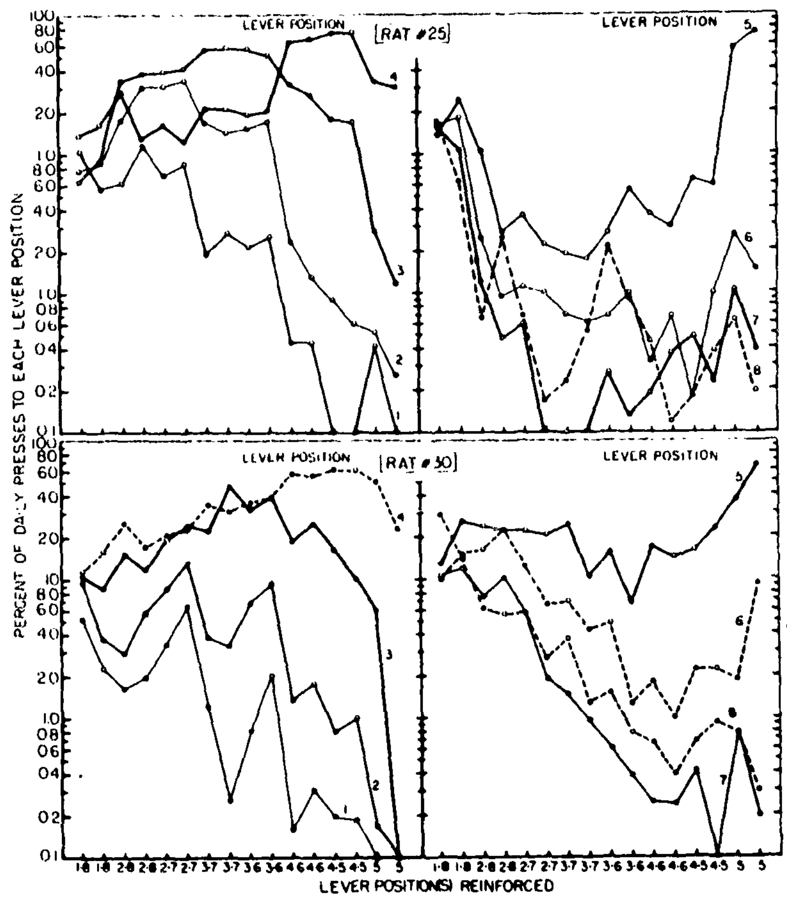

Figure 2. Changes in the daily percentages associated with a systematic reduction in the size of the "reinforcement zone". A percentage of 0.10 or less was plotted as 0.10. A solid datum point means that the percentage represented was significantly higher or lower (.05 level, two-tail test; Wallis & Roberts, 1956, p. 429) than the preceding percentage. Where two lines cross at a solid datum point the significant difference refers to the line showing the greater vertical displacement.

to each lever position as the RZ was decreased. The semilogarithmic plot was selected to give equal emphasis to the lever positions with low percentages. In addition to the direction of the change in the percentage of presses, Fig. 2 also indicates both the absolute and the relative amount of percentage change from day-to-day. The absolute amount of the change is read from the ordinate scale. Thus, when the RZ decreased from 2 - 7 to 3 - 7, the percentage of presses of Rat #25 to Position 2 decreased from 33.79 to 16.93%, a decrease of 16.86 percentage points; changing the RZ from 3 - 6 to 4 - 6 resulted in a drop from 17.05 to 2.42% or 14.63 percentage points. A measure of the relative drop associated with a change in the RZ is obtained by dividing the percentage of one condition by the percentage of the other. In the above example, 33.79 ÷ 16.93 = 1.99; 17.05 ÷ 2.42 = 7.04. Because of the characteristics of the logarithmic scale, these relative decreases may be estimated directly from Fig. 2 by comparing the vertical displacements. In the comparison given above, for example, the vertical displacement representing the change from 17.05 to 2.42% is almost three times as great as the vertical displacement representing the change from 33.79 to 16.93%.

Analyses of the relative drops on Positions 1, 2, and 3 were made for all the rats. The greatest relative decrease in the percentage of presses to Position 1 occurred for one rat when reinforcement for Position 2 was eliminated from the RZ, for 3 rats when reinforcement

for Position 3 was eliminated, and for the remaining rat when reinforcement for Position 4 was eliminated. The greatest relative decrease in the percentage of presses to Position 2 occurred for 3 rats when reinforcement for Position 3 was eliminated and for the other 2 rats when reinforcement for Position 4 was eliminated. The greatest relative decrease in the percentage of presses to Position 3 occurred for 2 rats when reinforcement for Position 3 was eliminated and for 3 rats when reinforcement for Position 4 was eliminated. Thus, for Positions 1, 2, and 3, the relative decrease in the percentage of presses to a given lever position was less, ordinarily, when reinforcement for that position was eliminated than it was when reinforcement for a higher position was eliminated.

Figure 3 provides central tendency and variability measures. With the Lever Position units, the largest mean lever displacement possible is 8.0 (occurring if all presses are made to Position 8) and the smallest is 1.0. The largest mean deviation possible is 3.50 (occurring if 50% of the presses are made to Position 1 and 50% to Position 8), and the smallest is 0.0 (occurring if all presses are made to the same Position).

Figure 4 provides various measures of the lever pressing behavior. In general, these curves show that as the RZ decreased (a) both the number of presses and the number of reinforcements increased, and (b) the number of presses per reinforcement increased. For one rat, the daily number of reinforcements is plotted as a function of the daily

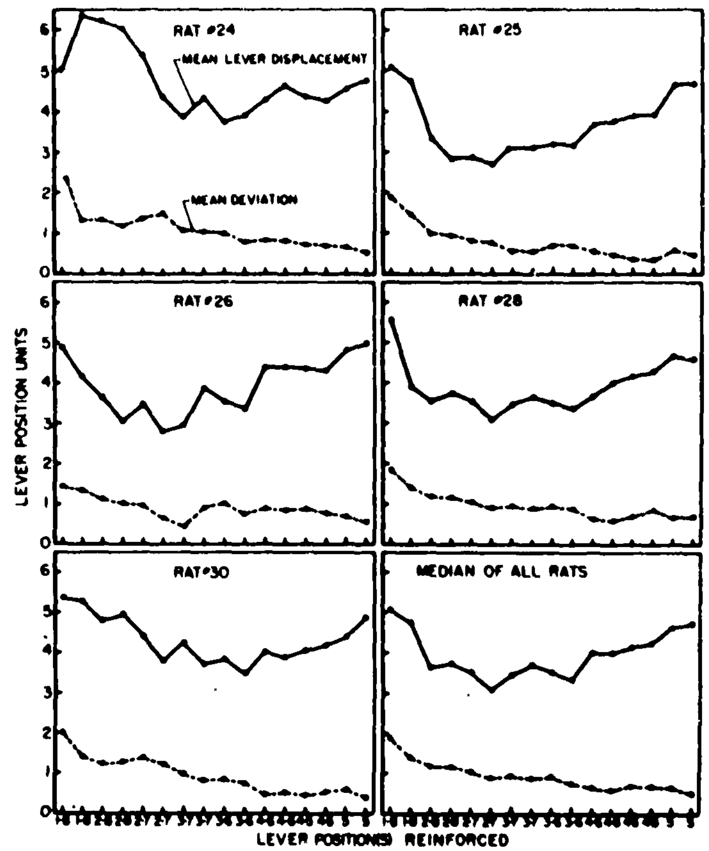

Figure 3. Central tendency and variability measures of lever displacement associated with a systematic reduction in the size of the "reinforcement zone".

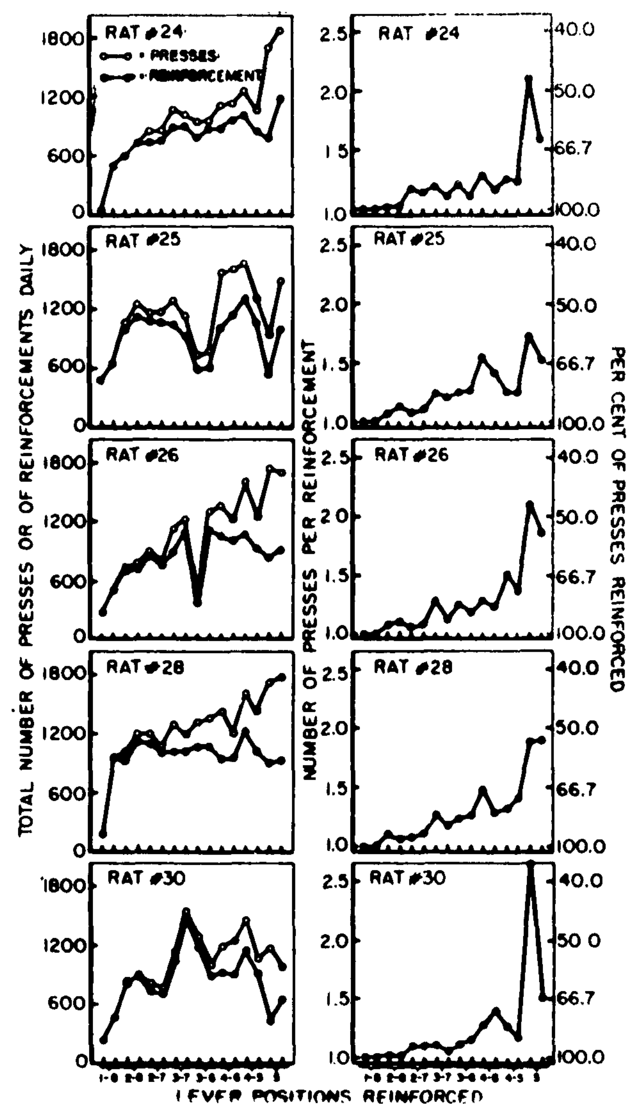

Figure 4. Changes in lever-pressing measures associated with a systematic decrease in the "reinforcement zone."

number of presses in Fig. 5.

Sample records of the cumulative number of reinforcements received by one rat during the daily sessions are given in Fig. 6. Presumably, these records are analagous to records of the cumulative number of presses. The daily records of Fig. 6 are representative of four of the rats; Rat #30 pressed at a lower, steadier rate, and its periods of no pressing occurred less frequently and were of shorter duration.

Figures 7 and 8 present distributions of the last 20 test days, Days 17-36. In every one of the hundred daily distributions of the twenty days the mode was Position 5. With few exceptions, more of the non-reinforced presses were to Position 4 than to any of the other non-reinforced positions. By the statistical test described in the Fig. 1 caption, each distribution of Fig. 8 differed significantly from the preceding distribution.

Figure 9 provides a semilogarithmic plot of day-to-day variations in the percentages for one rat. The percentage of presses to Positions 1, 2, 3, 7, and 8 were combined because they were all very low. For the other four rats, the percentage of presses to Position 5 are given in Fig. 10.

To determine whether the day-to-day changes in the percentage of presses to Position 5 were simply random variations, two runs tests were used. Each analysis for each of the five rats included the data of the 22 days (Days 15-36) on which only presses to Position 5 were

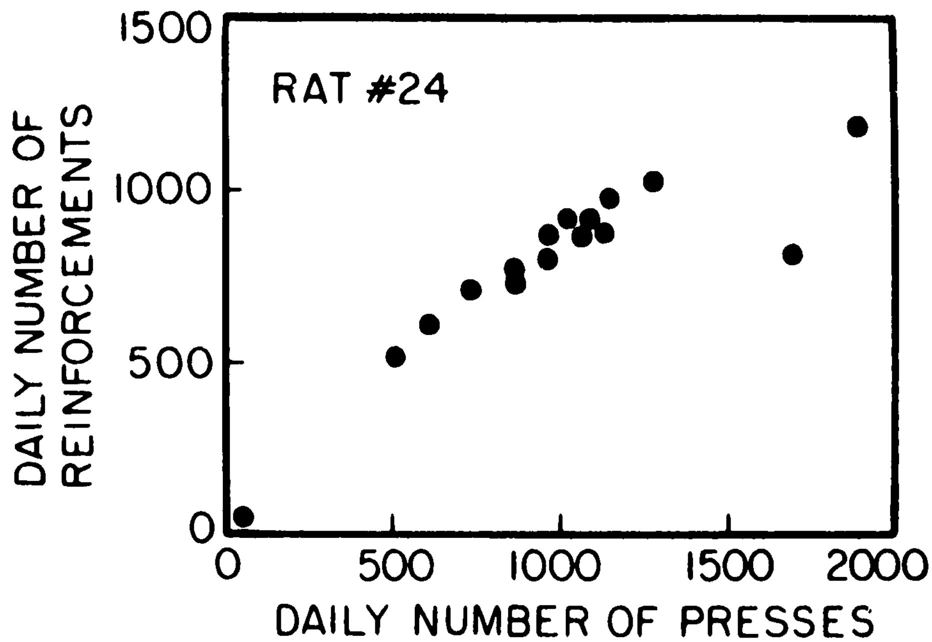

Figure 5. Number of reinforcements as a function of the number of lever presses.

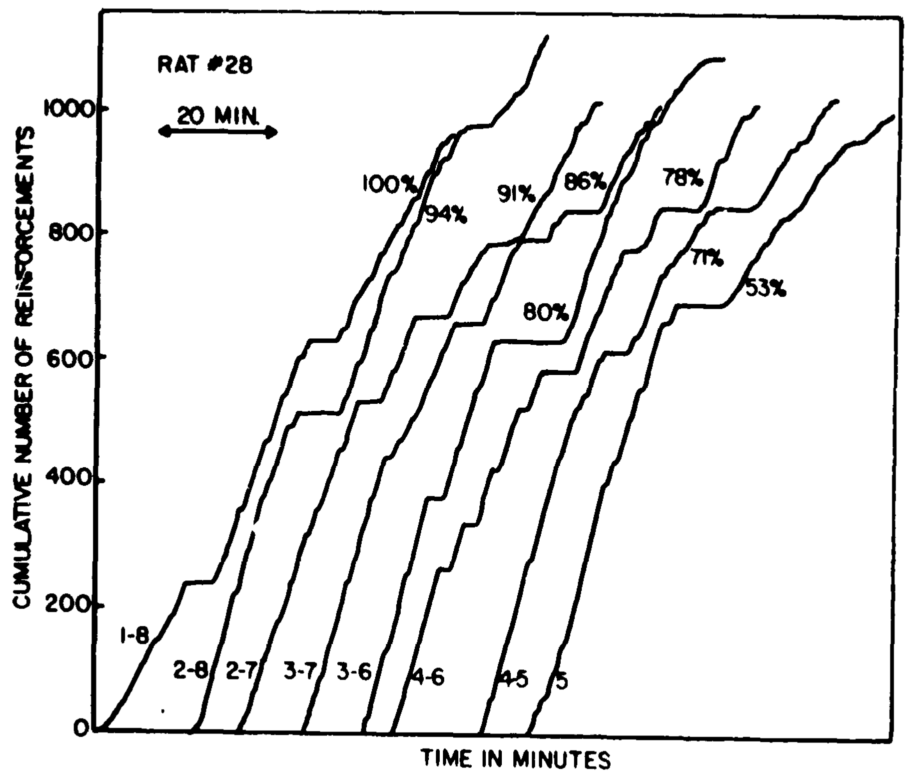

Figure 6. Cumulative number of reinforcements of second 1 hr daily session under each reinforcement condition. Lower numbers on curves indicate reinforcement zones; upper numbers give the percentages of presses reinforced.

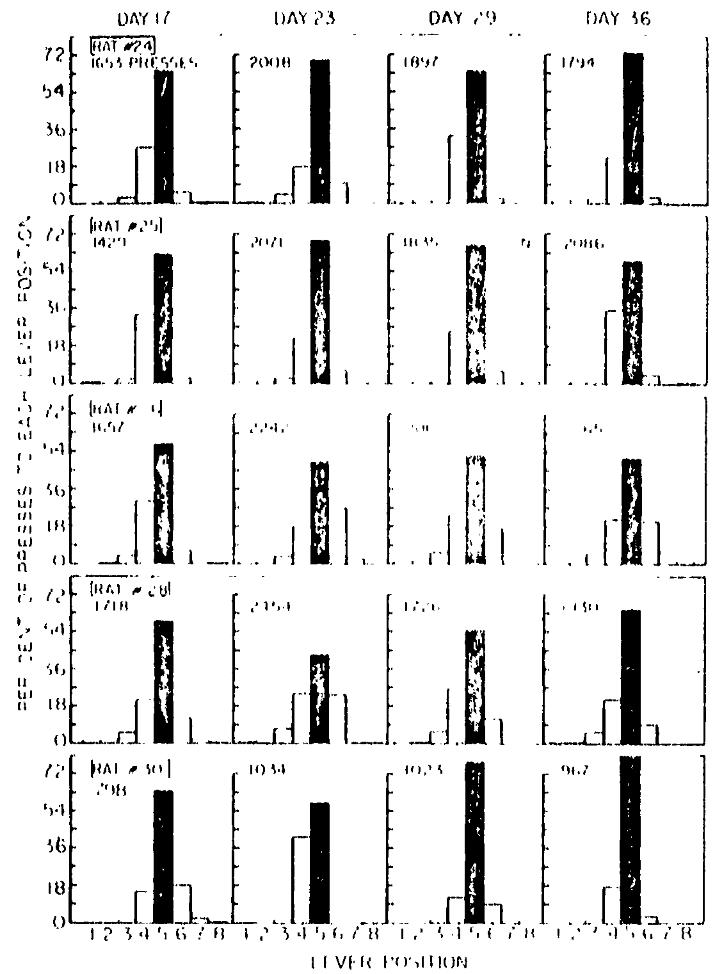

Figure 7. Sample daily lever displacement distributions during the period when the only presses reinforced were those to Position 5. See Fig. 1 caption for interpretation of $\underline{N}$

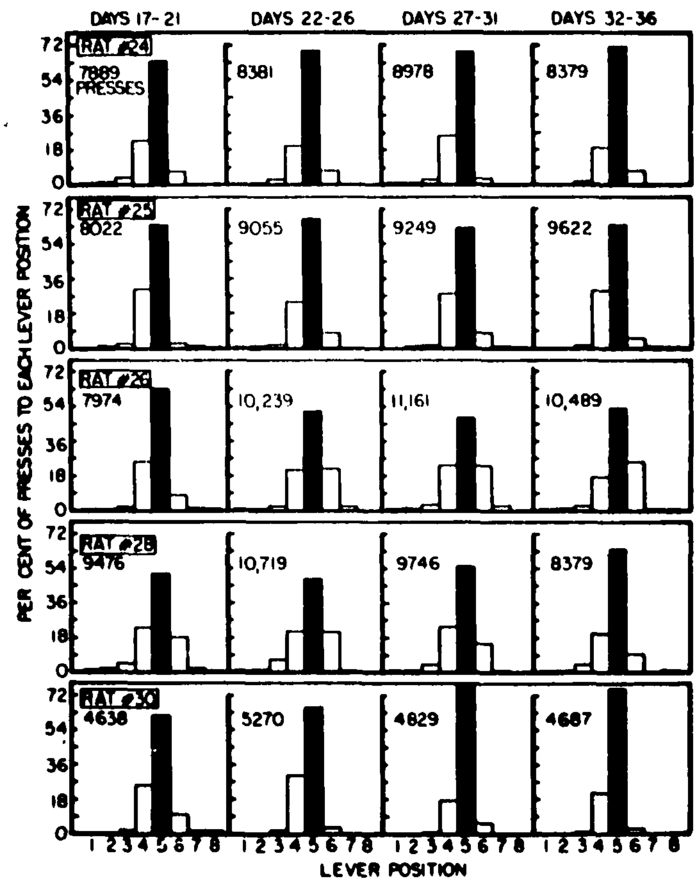

Figure 8. Lever displacement distributions based on presses during 5-day periods when the only presses reinforced were those to Position 5.

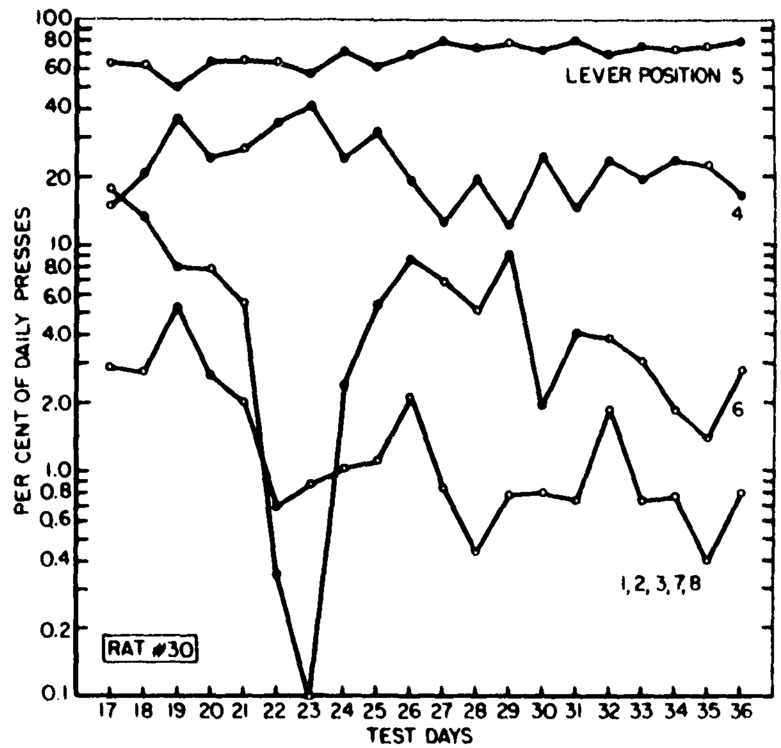

Figure 9. Changes in the daily percentage of presses to the lever positions when the only presses reinforced were those to Position 5. See the Fig. 2 caption for the meaning of a solid datum point.

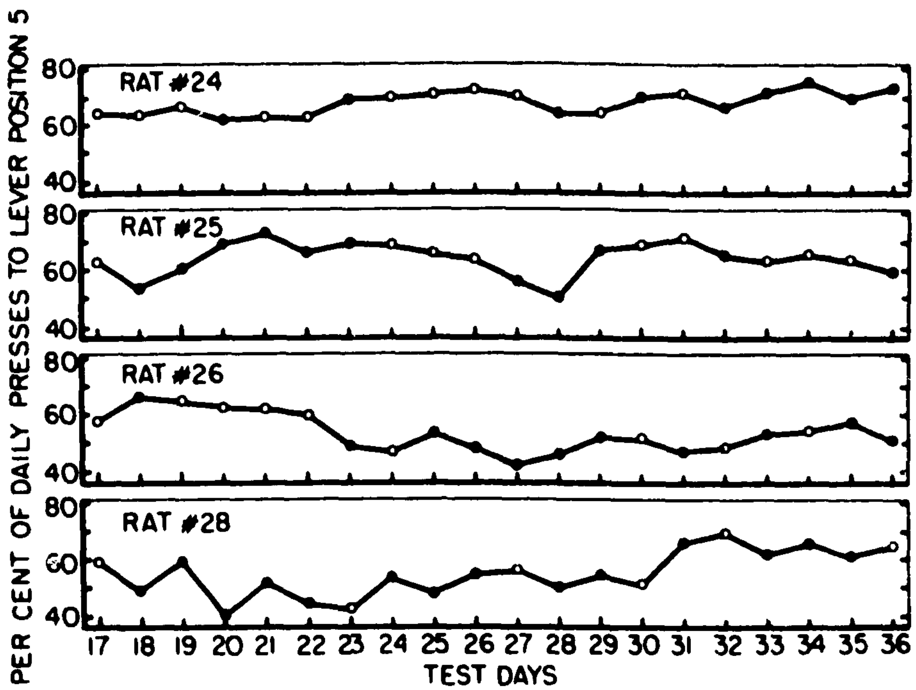

Figure 10. Percentage of presses to Lever Position 5 during 20 days on which the only presses reinforced were those to Position 5. See the Fig. 2 caption for the meaning of a solid datum point.

reinforced; significance at or beyond the .05 level was determined with "two-tail" tests. One test (Wallis & Roberts, 1956, p. 572) asked whether the series of daily Position 5 percentages tended either to fluctuate up and down or to continue in the same direction, up or down, more often than would be expected by chance. For two rats, Rats #25 and #26, this test indicated a significant tendency for the percentages to continue in the same direction; Days 18 - 23 of Rat #26 in Fig. 10 provide an example of this type of trend. A second runs test (Wallis & Roberts, 1956, p. 573) asked whether the general level of the series of Position 5 percentages increased or decreased significantly. Only Rat #24 showed a significant change, an increase, in the general level of the series.

For three of the rats, Fig. 11 provides a summary of the 36 test days. For the three rats of this figure and for the two rats not shown, the two runs tests mentioned above were used to evaluate trends during Days 15 - 36 in the series of P_{10}, P_{50}, and P_{90} values. The first runs test indicated, for Rat #26, a tendency for movements of the P_{10} values to persist in the same direction, up or down, more often than would be expected by chance. This same rat showed the same tendency with respect to both the P_{50} values and the P_{90} values. However, of the other four rats only one, Rat #30, showed a similar tendency, and for this rat the persistence in the direction of movement occurred only for the P_{90} values. The fifteen evaluations provided by the second runs test indicated no significant changes in the general level of any

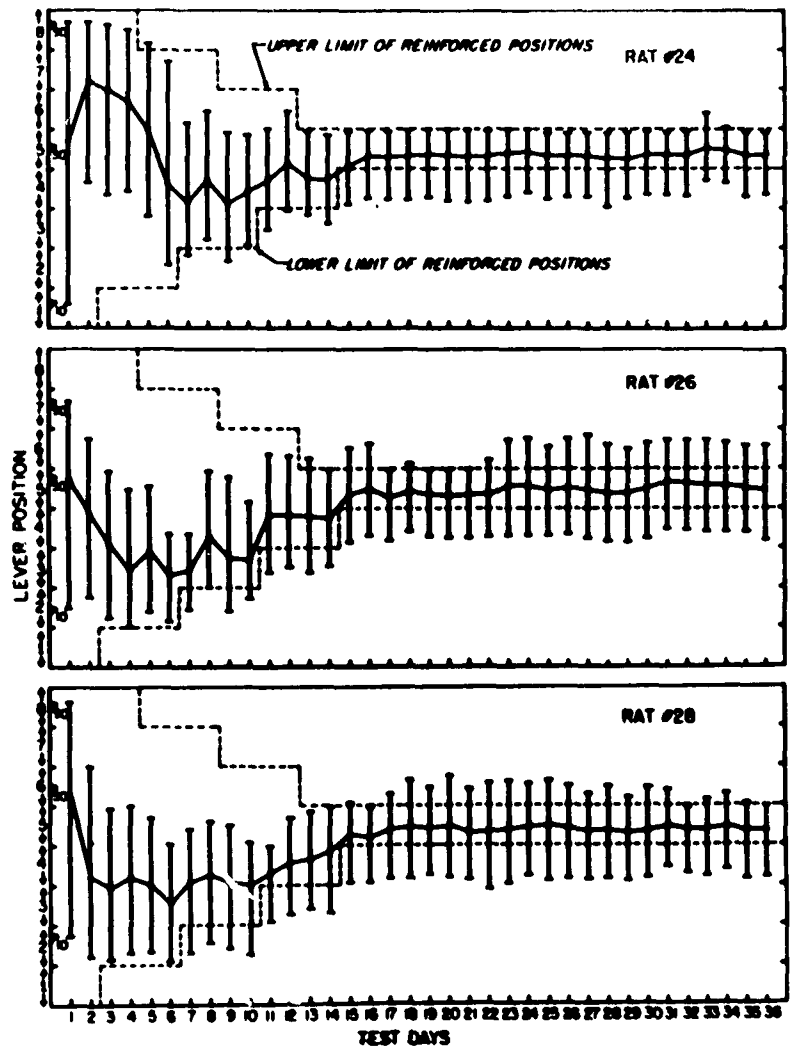

Figure 11. Median lever displacement (P_{50}) and range of middle 80% of daily distributions during the differentiation of a lever displacement response.

of the series of P_{10}, P_{50}, or P_{90} values for any of the rats.

A summary of the total number of lever presses to all positions is provided by Fig. 12.

DISCUSSION

The last column of distributions in Fig. 8 may be considered examples of a near-equilibrium state resulting from the combined influences of reinforcement for Position 5 presses and extinction for presses to all other positions. That these distributions reflect the differentiation procedure used is indicated by the fact that somewhat different distributions result with a slightly different procedure: when presses to a position other than Position 5 resulted in a 10-sec "time-out" period, distributions were decidedly more peaked than those of the present experiment (Herrick, 1963b).

It is worthwhile to consider the analyses in the results section with regard to theoretical and practical applications to differentiations. One of the conclusions of the study is that a powerful tendency toward "least effort" exists. This same tendency can be seen in the data of other differentiation studies in which the response property measured was displacement (Herrick,1963b), force (Arnold, 1945; Notterman & Mintz, 1962), and duration (Molliver, 1963). Murphy's displacement differentiation study (1943) with humans did not show this tendency toward "least effort". It is likely, however, that the "least effort" effect is a function of the absolute amount of "effort" required. A human

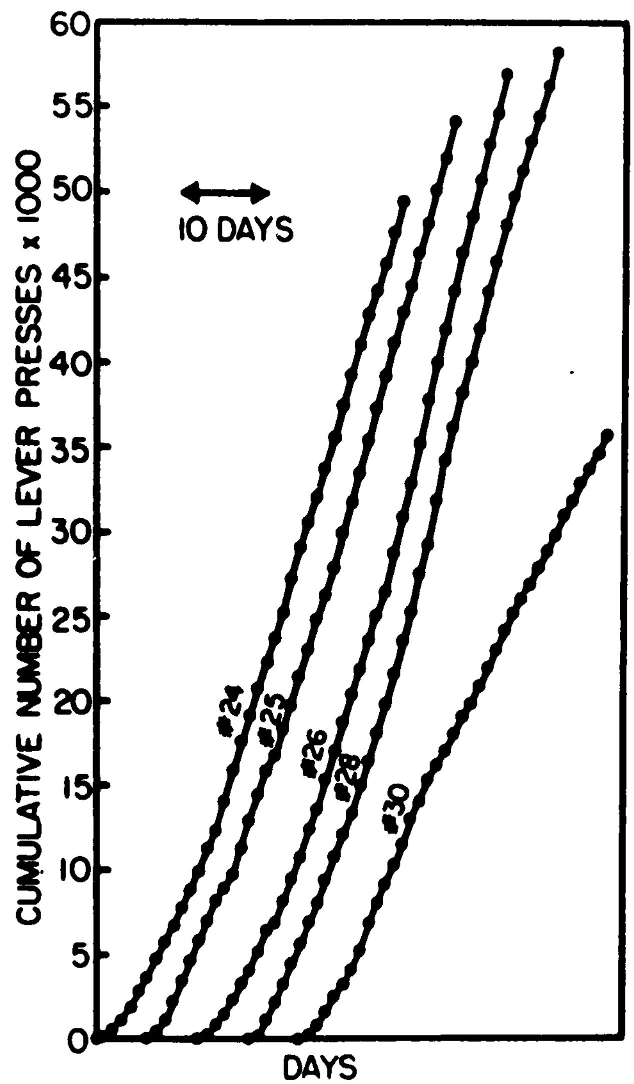

Figure 12. Cumulative number of lever presses during the 36 test days of the successive differentiation study. Each datum point represents 1 day.

subject, for example, may not tend toward the least force possible when the forces required range from 10 to 20 g, but he would probably do so when the forces required range from 10 to 20 kg. The above considerations suggest that in designing a differentiation procedure the experimenter should consider and, if possible, exploit the subject's tendency toward "least effort".

A second finding is that, by gradually approaching the final form of the response, many reinforcements are given for responses that later become ineffective for procuring reinforcement. If the resistance to the extinction of a response is, in fact, a function of the number of reinforcements received for the emission of that response, any procedure that strengthens responses that are to be extinguished subsequently is undesirable. A preferred differentiation procedure should provide minimal strength to all but the final form of the response.

A third point to be noted is the relationship between the size of the RZ and the number of presses per reinforcement (see Fig. 4). As Murphy (1943) has noted, this relationship may be described roughly by a positively accelerated curve: as the RZ decreases by steps of equal size, the number of presses per reinforcement goes up in increasingly larger steps. In other words, the differentiation becomes increasingly more and more difficult. This relationship suggests that, early in the differentiation, a shift from one RZ to the next could occur more quickly without risking extinction (cf. Herrick, 1963b).

It also seems desirable to provide an increasingly greater amount of training with each successively smaller RZ.

Consideration of the three factors, namely, "least effort", gradual approximation, and increasing difficulty, suggests that, if one's ultimate aim is to produce a particular response expeditiously, certain modifications of the present procedure are desirable. Applied to the task of the present experiment, the following procedure is suggested. First, reinforcement for Positions 1 - 8 would prevail only long enough to insure that pressing would continue after the RZ was reduced. Then the zone would be reduced, successively, to 5 — 8, 5 — 7, to 5 — 6, and finally to Position 5, with an increasingly greater amount of training with each successively smaller RZ. Such a procedure would prevent reinforcement for Positions 1, 2, 3, 4. Also, since the lowest position within the RZ would always coincide with the final RZ, use would be made of the rat's "least effort" tendency. Finally, because of "least effort", prolonged training in the latter stages should strengthen the response to Position 5 more than the responses to the other positions.

REFERENCES

Arnold, W. J. An exploratory investigation of primary response generalization. J. comp. Psychol., 1945, 38, 87-102.

Herrick, R.M. Lever displacement during continuous reinforcement and during a discrimination. J. comp. physiol. Psychol., 1963, in press. (a)

Herrick, R.M. Lever displacement during a discrimination-differentiation. J. comp. physiol. Psychol., 1963, in press. (b)

Herrick, R.M. & Karnow, P. A displacement-sensing, constant-torque response lever. J. exp. Anal. Behav., 1962, 5, 461-462.

Molliver, M.E. Operant control of vocal behavior in the cat. J. exp. Anal. Behav., 1963, 6, 197-202.

Murphy, M.J. The differentiation of a response--An exploratory study with human subjects. Abridgement of Ph.D. dissertation, New York University, 1943.

Notterman, J.M. & Mintz, D.E. Exteroceptive cueing of response force. Science, 1962, 135, 1070-1071.

Pearson, E.S. & Hartley, H.O. (Eds.) Biometrika tables for statisticians, Vol. I. Cambridge: University Press, 1956.

Wallis, W.A. & Roberts, H.V. Statistics: A new approach. Glencoe, Ill.: Free Press, 1956.

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The Successive Differentiation of a Lever Displacement Response: by Robert M. Herrick. 24 July 1963 29 pp.

Maximum displacements of lever presses by rats were recorded under 8 successively-smaller "reinforcement zones" (RZ). The largest RZ included displacements from 3.29° to 44.01°; the smallest, from 23.65° to 28.74°. Work expended was linearly proportional to displacement. As the RZ decreased, displacement distributions reflected a "least effort" tendency: distributions peaked at the lower limit of RZ and most non-reinforced presses fell just below the lower limit. Successive distributions (a) differed significantly, (b) showed reduced variability, and (c) indicated more presses, more reinforcements, and more presses per reinforcement. The effect on a given response class was less, relatively, when that class was eliminated from the RZ than it was when a higher response class was eliminated. A modified differentiation procedure was recommended.

1. Report NADC-MA-6307
2. Subtask MR005.03-0002.16
Report No. 11
Weptask R360
FR102/2021/R01/10 1001
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